Concepts For Ocean Worlds Life Detection Technology

Autonomous Melt-Probe Penetration of Dirty Ice with Clean Sampling for Life Detection

Completed Technology Project (2016 - 2018)

Project Introduction

Access to subsurface material and oceans through water-ice crusts is a goal common to exploration of all ocean worlds. Probes that melt their way through ice are, thus far, the only technology demonstrated to penetrate ice autonomously to depths on the order of kilometers, as will be required to reach an ocean on, e.g., Europa. Moreover, melt probes operate in ice at all relevant temperatures, with internal temperatures for electronics and instrumentation near 273K. Such probes are thus strong candidates for subsurface access and life detection on ocean worlds. However, an ocean worlds melt probe will have to penetrate ice laden with particulates from, e.g., meteoritic or comet dust infall, which accumulate in front of the probe, insulate the melt head, and arrest progress. At the same time, the probe must acquire melt- or ocean-water samples and deliver them without contamination to life-detection instruments. These functions must be accomplished under more severe constraints on power (in foreseeable landed systems) than previous melt probes can meet. Melt probe power requirements decrease rapidly with decreasing size. We show that a probe with dimensions near those of our small, newly field-tested probe could attain meter-per-hour descent speeds on ocean worlds, even at 100K temperature, using thermal power comparable to that generated radiogenically in a General Purpose Heat Source. Such speeds are sufficient to reach kilometers-deep subglacial water within a nominal 30-day lander life time. Such an approach would entail major commitments of engineering effort and national resources of plutonium. Precisely because the commitments would be large, it is critical to establish first that essential, component-level functions of subsurface exploration can actually be demonstrated in sufficiently small probes. Primary technical risks on a path to flight hardware therefore entail simplification and size-reduction of hardware to penetrate 'dirty' ice, and to acquire 'clean' samples for life-detection. The objective of this project is retirement of those risks. We bring to this work unique experience in each component. Two members of our team have developed a simple, robust probe, which has reached 400 m depth in Greenland and demonstrated penetration rates of 6.6 meters per hour (these are the second-greatest depth and highest speed achieved by melt probes on Earth to date). We have demonstrated autonomous descent based on the geometry and power-balance in our probe, rather than computationally intensive control algorithms. Our third team member has developed and tested in Antarctica a melt-probe based, microbiologically and geochemically clean sampling system, the size and complexity of which we will reduce. Our specific objectives are thus: (1) to develop a simplified pump and jetting mechanism (currently TRL 3), integrate it with our field-tested melt probe (TRL 4), and to quantify in the laboratory, the characteristics of particle-laden ice that the system can penetrate as a function of jetting parameters; (2) to develop, initially also in the laboratory, clean acquisition and transfer of water samples (currently TRL 3-4 based on Antarctic field experience); and finally (3) to demonstrate dirty ice penetration and clean sampling in an integrated system small enough to be powered radiogenically on ocean worlds, and in a

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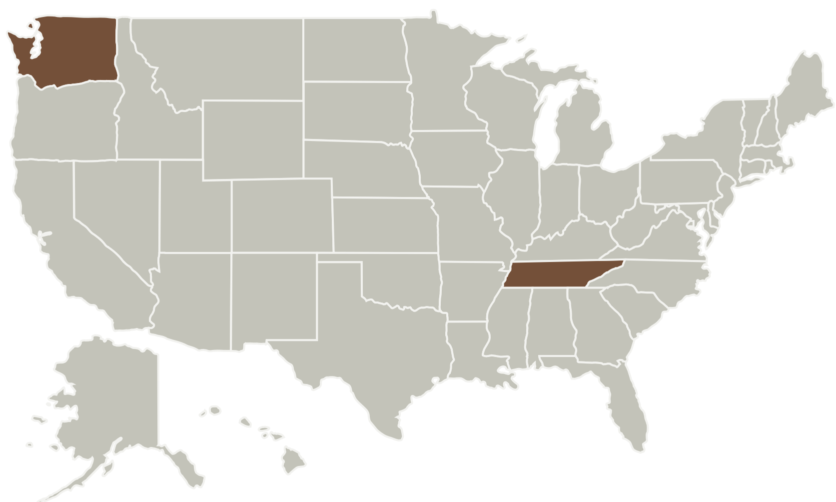
relevant environment (to a depth of 50 m on a dusty alpine glacier in Washington State, with our exit TRL at or approaching TRL 5). We presently envision the next step toward mission implementation to be testing in ice simulating that on ocean-worlds surface at relevant temperatures. We are in active conversation with the JPL Space Technology Program Office on mission implementation.

Anticipated Benefits

Results of this project will directly support development of flight hardware for subsurface access on icy moons in the outer solar system, likely beginning with the second Europa lander, which is presently in early development at JPL. Thus far, melt-probe technology is the only demonstrated method of autonomous ice penetration to depths of kilometers, but melt probes have not previously demonstrated acquisition of uncontaminated samples for life detection, nor have such probes been robust in penetrating dirty ice (as is foreseen on ocean worlds). Our development is focussed on technical risk reduction in both of these functions, within the confines of a probe small enough to meet anticipated constraints on thermal power in landed systems in the outer solar system.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Lead Organization:

University of Washington-Seattle Campus (UW)

Responsible Program:

Concepts for Ocean Worlds Life Detection Technology

Project Management

Program Director:

Carolyn R Mercer

Program Manager:

Carolyn R Mercer

Principal Investigator:

Dale P Winebrenner

Co-Investigators:

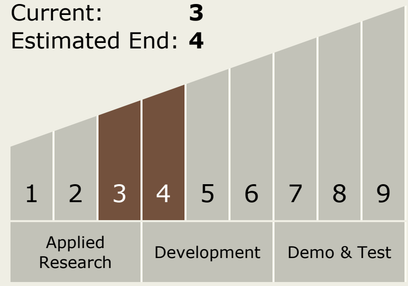
William T Elam
Lynn M French
Jill A Mikucki

Organizations Performing Work	Role	Type	Location
University of Washington-Seattle Campus(UW)	Lead Organization	Academia Alaska Native and Native Hawaiian Serving Institutions (ANNH), Asian American Native American Pacific Islander (AANAPISI)	Seattle, Washington

Primary U.S. Work Locations	
Tennessee	Washington

Technology Maturity (TRL)

Start: **3**
Current: **3**
Estimated End: **4**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  └ TX08.3 In-Situ Instruments and Sensors
    └ TX08.3.4 Environment Sensors

Target Destination

Others Inside the Solar System